ESD-TR-68-117 MTR-565

FIELD TEST RESULTS OF THE ANDEFT/SC-320 4800 B/S HF MODEM

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APRIL 1968

M. P. Talbot, Jr.

Prepared for
DEVELOPMENT ENGINEERING DIVISION
AEROSPACE INSTRUMENTATION PROGRAM OFFICE
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

Project 705B
Prepared by
THE MITRE CORPORATION
Bedford, Massachusetts
Contract AF19(628)-5165

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FOREWORD

This report was prepared by the Communications Techniques Department of The MITRE Corporation, Bedford, Massachusetts, under Contract AF 19(628)-5165. The work was directed by the Development Engineering Division under the Aerospace Instrumentation Program Office, Air Force Electronic Systems Division, Laurence G. Hanscom Field, Bedford, Massachusetts. Robert E. Forney served as the Air Force Project Engineer for this program, identifiable as ESD (ESSID) Project 5932, Range Digital Data Transmission Improvement.

REVIEW AND APPROVAL

This technical report has been reviewed and is approved.

OTIS R. HILL, Colonel, USAF
Director of Aerospace Instrumentation Program Office

ABSTRACT

During June 1967, digital data transmission tests were conducted on a High-Frequency radio circuit between MITRE and the Naval Electronics Laboratory. The HF modem tested was the ANDEFT/SC-320 which was designed by General Dynamics/Electronics Division for data transmission at rates of 4800 b/s in a 3 KHz bandwidth. The test results demonstrate that this modem which operates at twice the data rate of current HF modems has comparable bit error rate performance.

ACKNOWLEDGEMENTS

The ANDEFT/SC-320 HF modem and the sounder tests were made possible by the assistance and cooperation of the Naval Electronics Laboratories. In particular, we express our gratitude to Mr. F. Tirpak for his efforts in coordinating the tests at NEL and also the operating personnel who aided us in achieving frequency changes.

We also wish to acknowledge the assistance of Messrs. M. B. Gray and C. Durant of General Dynamics Dynamics/Electronics Division.

Finally, the MITRE field test personnel are acknowledged for their cooperation in running an arduous shift schedule including N. Cox, D. Dewey, S. Forde, R. Gilliatt, and L. James who were responsible for the collection of the data. J. D. Bosia and K. Brayer are also acknowledged for their aid in reducing the data.

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SECTION I

INTRODUCTION

BACKGROUND

The Air Force Electronic Systems Division, in support of the National Range Division's (NRD) program to upgrade existing HF digital data communication links, entered into a prototype development program with General Dynamics/Electronics Division (GD/E), Rochester, New York. The purpose of this program was to develop a HF modem capable of transmitting data at rates up to 4800 b/s in a 3 KHz bandwidth with performance that is comparable to present 2400 b/s HF modems. The prototype developed by GD/E under contract AF 19(628)-5536 is the ANDEFT/SC-320.

The ANDEFT/SC-320 test program was broken down into three phases. The Phase I acceptance tests, which included back-to-back, additive, white Gaussian noise tests, were successfully completed in September of 1966 [1]. The Phase II tests included testing of the ANDEFT/SC-320 on the GD/E HF Path Simulator [2] and were completed in April of 1967. The Phase III tests were live on the air tests which took place in June 1967 between the Navy Electronics Laboratory (NEL) in San Diego and MITRE. Ionospheric soundings were also made concurrent with the modem tests in an effort to determine ionospheric propagation conditions. This report concerns itself only with the Phase III modem test results.

PROGRAM OBJECTIVES

The two objectives of the ANDEFT development program are (1) the development of a HF modem capable of transmitting data at a rate of 4800 b/s through the HF medium (the ionosphere) and (2) the integration of the

ANDEFT/SC-320 modem with forward error control equipment to provide an information throughput capability in excess of what is presently available. Another objective is modification of the present ANDEFT/SC-320 to transmit at data rates of 7200 and 9600 b/s. The first objective will be the subject of this report. The second objective will require analysis of the data collected on tape to obtain bit-by-bit error patterns and the development of suitable coding equipment.

SECTION II

TEST CONFIGURATION

The MITRE-NEL experimental data-communications link is depicted in Figure 1. The distance between transmitter and receiver site locations is approximately 2571 statute miles. Six frequencies with a 6 KHz frequency allocation were available for either data or voice (order wire) transmission from NEL to MITRE. Five frequencies with a 3 KHz frequency allocation were available and used solely for voice (order wire) transmission from MITRE to NEL.

The terminal equipment used in the MITRE-NEL ANDEFT/SC-320 test program is shown in Figure 2. Basically, the operation of the link can be described as follows. At San Diego the fixed 52-bit pattern generated in the word generator is fed to the ANDEFT/SC-320 modulator where the 64 data tones are phase-modulated by the incoming data stream. All the phase-modulated tones plus two reference tones are summed together to form a composite audio signal lying primarily in the bandwidth from 360 to 3040 Hz. This signal is then used to amplitude modulate a radio frequency (RF) carrier. The AN/URC-32 transceiver may be used in the upper sideband, lower sideband, and twin sideband modes. The RF signal is then amplified by the linear power amplifier (LPA) and transmitted to MITRE via a log periodic antenna. During the tests a one-kilowatt average power signal was transmitted. After reception at MITRE the signal is demodulated and the resultant audio signal is both recorded and fed to the ANDEFT/SC-320 demodulator. (The recorded audio signal may be used for post-test simulation of the HF channel.) The received data sequence containing errors is compared with a locally generated data sequence which is identical to and in synchronism (bit and frame) with the transmitted data sequence. The

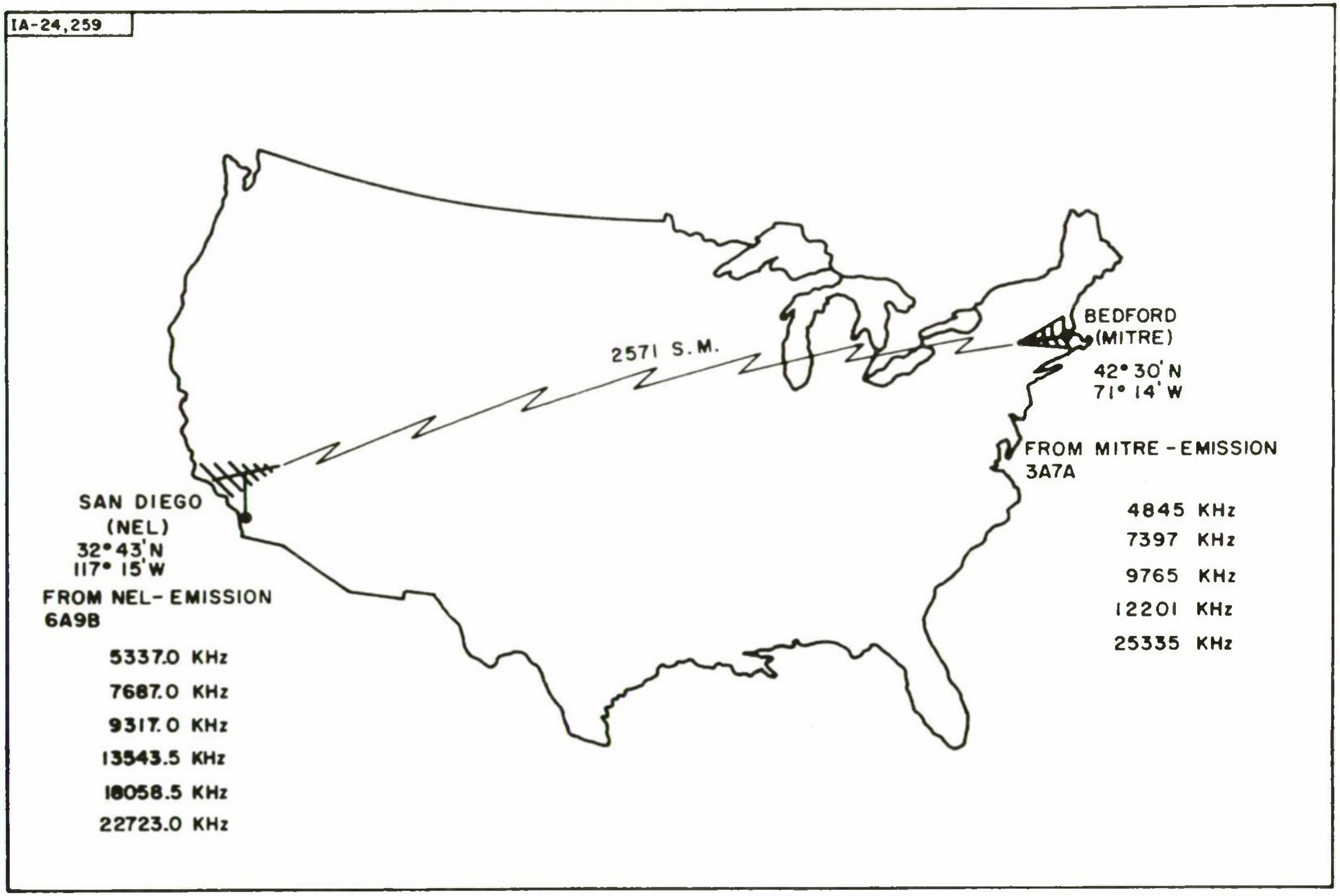

Figure 1. MITRE-NEL Experimental Data Communications Link

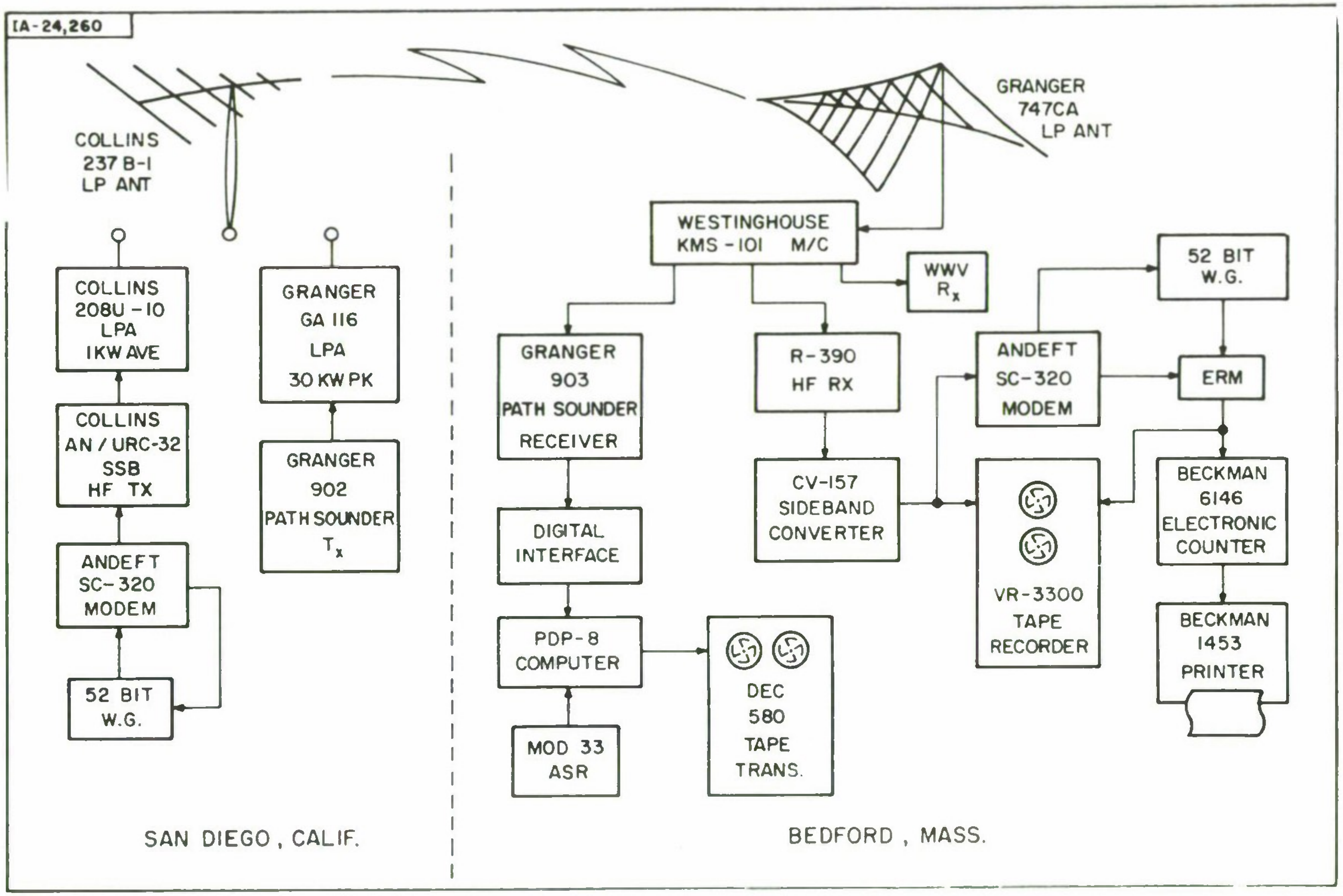

Figure 2. Block Diagram of the Terminal Equipment Used in the MITRE-NEL ANDEFT/SC-320 Test Program

digital errors are recorded on magnetic tape and counted and printed as one-minute cumulative totals on paper tape. The cumulative one-minute error printouts are used to generate the cumulative performance curves given in Section VI.

Also operating on the MITRE-NEL link was Granger path sounding equipment with transmitter located at NEL and receiver located at MITRE as shown in Figure 2.

SECTION III

DESCRIPTION OF THE ANDEFT/SC-320 HF MODEM

The ANDEFT/SC-320 HF modem is a four-phase, frequency-differential, PSK system which uses sixty-six tones to achieve data transmission rates up to 4800 b/s. The tones are spaced 40 Hz apart beginning at 400 Hz and ending at 3000 Hz. Two reference tones are used for bit timing synchronization. The sixty-four information tone channels are keyed at 37.5 symbols per second (with 2 bits/symbol) which results in a transmitted symbol duration of 26 2/3 milliseconds. The baseband tone positions are shown in Figure 3.

The feature that distinguishes the frequency-differential from the time-differential PSK system is the use of an adjacent tone in frequency as a phase reference instead of an adjacent symbol in time. The phase detection process is relatively unaffected by phase changes introduced by the HF medium because such phase changes are highly correlated for closely-spaced frequencies. Figure 4 illustrates the ANDEFT/SC-320 phase detector. First, the tones are dc correlated with a locally generated reference to obtain the phase angle of each received tone. Second, this phase angle is transferred to a sinewave at a common processing frequency (f_p) by modulation and addition. Finally, the phase comparison is made and ideally any phase changes introduced by the HF medium are cancelled out. The phase-difference is then converted to two bits of information in the character decision process. The 26 2/3 milliseconds symbol interval of the modem is divided as shown in Figure 3. The middle 25 milliseconds is used in the correlation detection process while the remaining 1 2/3 milliseconds provides a time guard band. The long detection interval creates a tolerance to large multipath delay

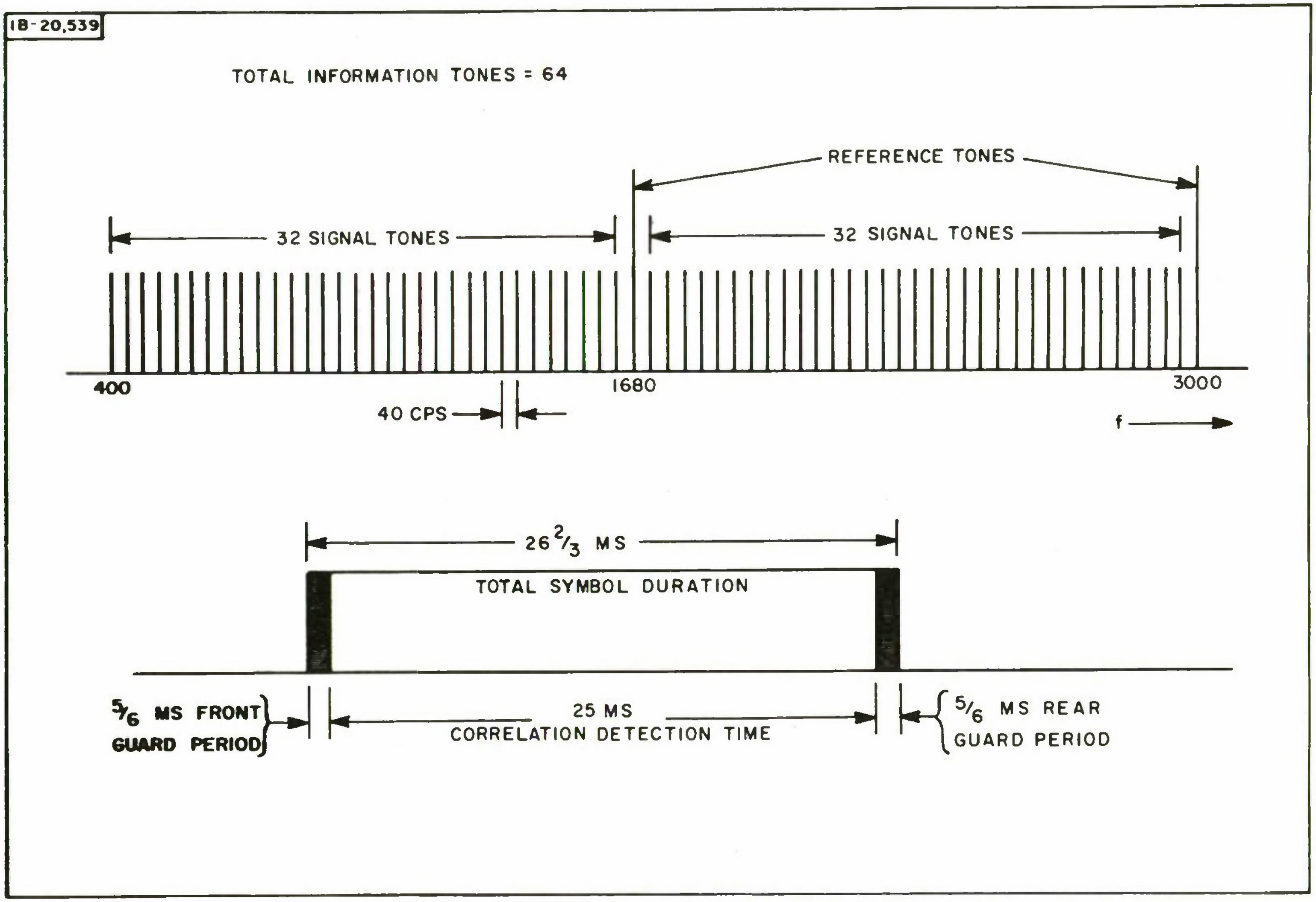

Figure 3. ANDEFT/SC-320 Tone Configuration and Symbol Duration

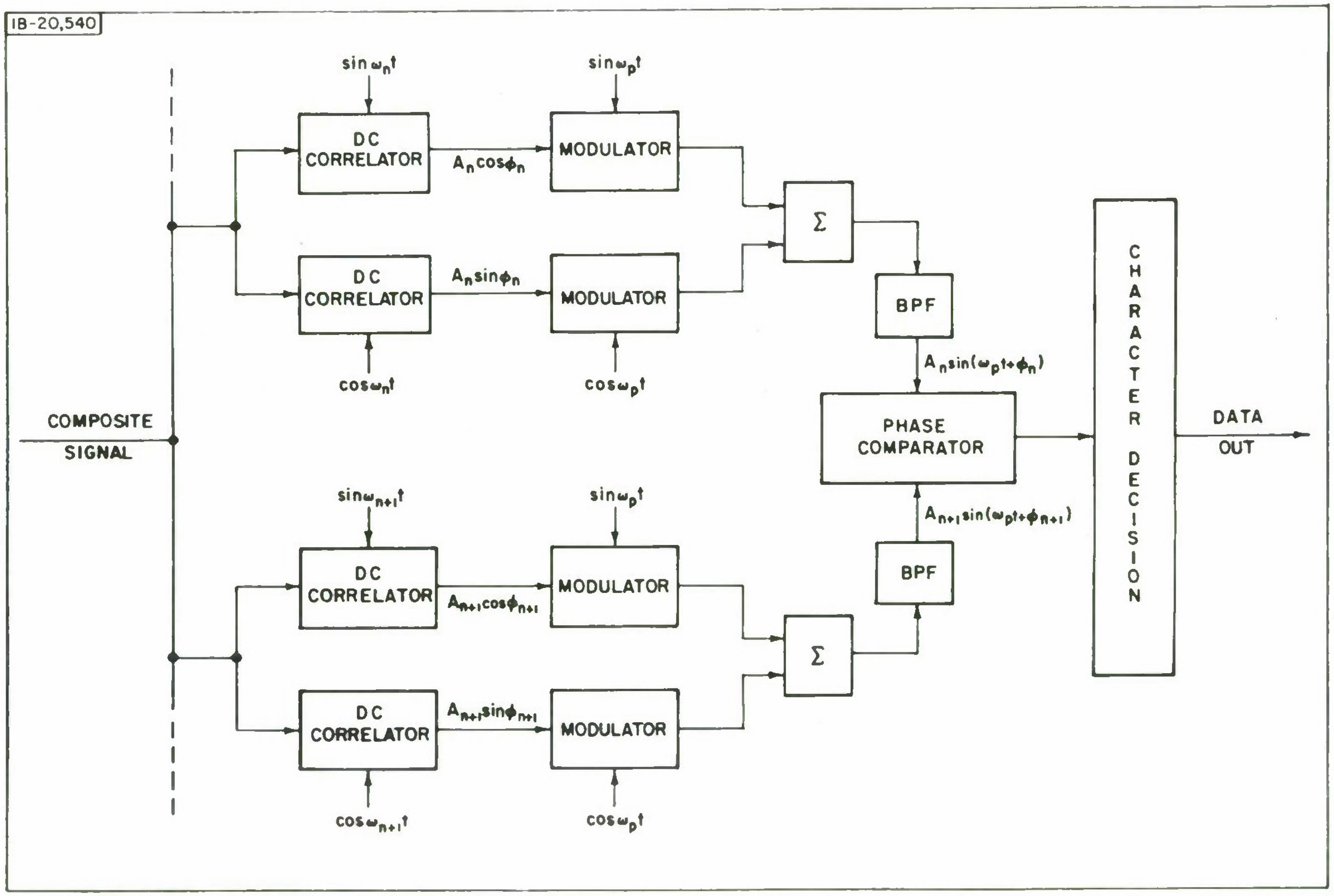

Figure 4. Simplified Block Diagram of the Phase Detection Process of the ANDEFT/SC-320

spreads while the short time guard band is used to achieve immunity to small delay spreads. An eight-way segmented AGC is also used to accommodate the frequency selective fading.

The modem also has the capability of equal-gain, dual reception diversity. In addition, the modem may use in-band frequency diversity in some of its modes of operation. Table I lists the modes of operation of the ANDEFT/SC-320.

Table 1

Operating Modes of the ANDEFT/SC-320

Data Rate (b/s)	Modulation	Reception Diversity	In-Band Frequency Diversity
4800	4-phase	Dual	None
2400	4-phase	Dual	Dual
2400	2-phase	Dual	None
1200	2-phase	Dual	Dual
600	2-phase	Dual	Quad

The ANDEFT/SC-320 prototype HF modem is so constructed that expansion to 7200 b/s and then to 9600 b/s can be accomplished without major mechanical or electrical redesign. The 7200 b/s and 9600 b/s data rates can be obtained by going to 8-level phase modulation for 7200 b/s plus two-level amplitude modulation for 9600 b/s.

SECTION IV

OPERATIONAL EXPERIENCE

GENERAL

The ANDEFT/SC-320 HF modem tests were performed during the period 7 June to 23 June 1967 inclusive. The transmitting site was at NEL in San Diego, California and the receiving site was at the MITRE Corporation in Bedford, Massachusetts. The receiving antenna at MITRE was a Granger 747CA Log-Periodic Antenna. The availability of only a single antenna precluded the use of dual space diversity reception. Hence, the only diversity available for 4800 b/s transmission tests was an out-of-band frequency diversity (OBD). The use of OBD, however, reduces the SNR on each path and makes the signal more susceptible to QRM; i.e., 6 KHz bandwidth is required for OBD versus 3 KHz for dual space diversity.

TEST DATA

During fourteen days of operation, approximately 69 hours of test data were collected. Of this total approximately 63 hours of data were recorded on magnetic tape. This includes a recording of both the digital errors and the voice-frequency (audio) signal at the input to the demodulator. The former may be useful for obtaining error statistics and the latter may be used for post-test playback. The data runs were normally 10 minutes long to permit sounder operation at 15-minute intervals. However, longer runs of 45 and 90 minutes were made when the sounder was off the air. No data was collected during the tests for error rates in excess of 10^{-1}. Also, no data was collected under severe QRM conditions.

Two types of test patterns were used; one contained all "ones" and the other was a fixed 52-bit pseudo-random pattern. The all "one" pattern represents a valid character for all of the modem's modes of operation. Hence, this recorded data may be used to compare the modem's error rate performance at different bit speeds. The 52-bit pseudo-random pattern more closely approximates the transmission of actual data. Hence, the data obtained with this test pattern is more suitable for comparing the cumulative performance of the various modes of operation used during the test. Also, this latter data is more suitable for developing error statistics from the data.

Five distinct modes of operation were used during the tests. These are listed in the following table with the approximate number of hours of collected data for each test mode.

Table II

Test Mode Description

Test Mode	Data Rate (b/s)	Test Pattern	Diversity	Hours
1	4800	52	None	16
2	4800	52	OBD	7
3	4800	"11"	OBD	16
4	4800	"11"	None	2
5	2400	52	IBD*	28

Figure 5 gives the hours (EDT) of operation for each day of the tests. The time inserted within the bar represents the amount of time on the air. However, the total length of the bar also includes additional time for sounder operation and for occasionally missed ten-minute tests. Early morning data

*IBD denotes the use of in-band frequency diversity.

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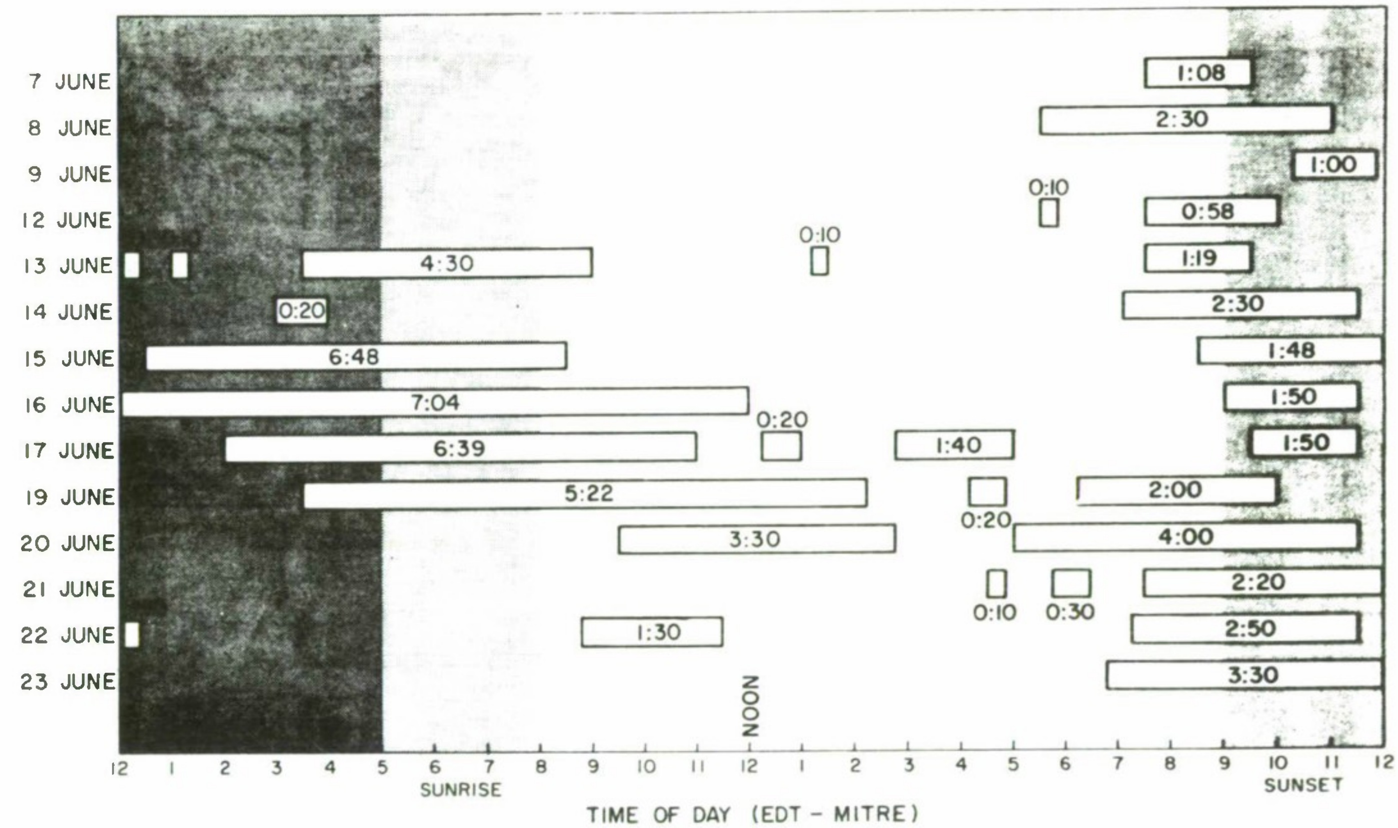

Figure 5. ANDEFT/SC-320 Operating Hours Diagram – June 1967

i.e., from 2400 to 0800 hours EDT, was recorded during a six-day period from 13 June until 19 June 1967 in order to obtain data on the lower frequencies. Although the period from 1200 to 1800 hours EDT might be considered prime time for HF transmission, the least amount of data was collected during this period because of severe QRM problems on all of the assigned frequencies. The best results in terms of modem performance and amount of data collected was in the evening from 1800 until 2400 hours EDT.

OPERATIONAL FREQUENCIES

Figure 6 is a plot of the data runs versus time of day. Also shown are the ESSA, MUF and LUF "Ionospheric Predictions" for (4,000) F_2. The actual data runs indicate times when the MOF exceeded the predictions. Some general observations on each of the assigned frequencies are made concerning the following: (1) QRM, (2) the noise or multipath limitation, and (3) the general availability of the frequency for transmission.

The highest frequency at 22 MHz was the "best" frequency in terms of the quantity and quality of the collected test data. Transmission on this frequency was typically noise limited; however, some narrowband QRM was observed on this frequency. This frequency was normally available for some time between 0800 and 2400 hours with the hours between 1800 and 2200 hours being favored.

The 18.1 and 13.1 MHz frequencies were usually unavailable during the daylight hours due to severe QRM conditions rather than poor propagation conditions.

The 9.32 and 5.34 MHz frequencies were unavailable for transmission during the tests. The former was unavailable because of QRM while the latter was unavailable because of the high LUF.

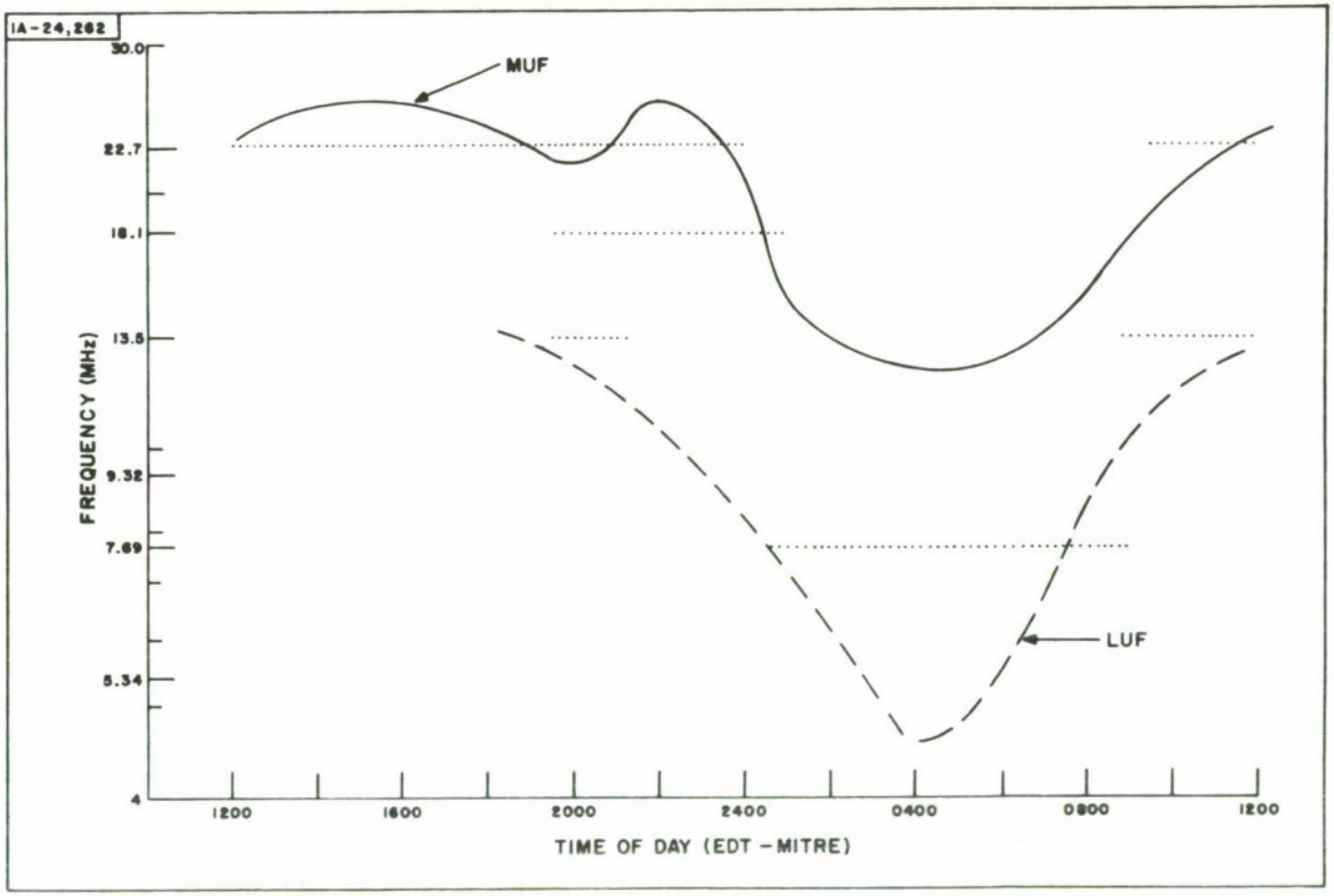

Figure 6. ANDEFT/SC-320 Test Experience – June 1967

The 7.69 MHz frequency was used for transmission between 2400 and 0800 hours. This transmission was typically multipath limited. The constant presence of severe QRM on one sideband precluded the use of any OBD diversity.

OPERATIONAL DIFFICULTIES

The lack of usable transmission frequency assignments plus the severe QRM limited the number of data runs and the quality of the runs. In addition, another factor limiting modem performance was a poor amplitude transmitter characteristic. This characteristic was due to the AN/URC-32 HF Transceiver used during the tests. This exciter was designed for voice transmission and low-speed data transmission. The amplitude characteristics for both sidebands are shown in Figure 7. The lowest tone at 400 Hz in the ANDEFT/SC-320 tone spectrum is degraded 6.0 db for the lower sideband and 10.0 db for the upper sideband. Other nearby tones are also affected, but less severely. This factor limited the modem's "best" performance.

The effect of the transmitter's amplitude characteristic is shown in Figure 8. In this figure the number of errors on each tone for three separate 10-minute runs is plotted versus the tone number which locates the tone in the ANDEFT/SC-320 spectrum; i.e., tone 1 is located at 400 Hz, etc. The number of errors on each tone is directly proportional to the tone error rate since the same number of bits is transmitted on each tone. All three runs were affected by the transmitter characteristic; however, the average error rate for the three runs was affected differently. Run 303 was the cleanest of the three, but it also exhibits some narrowband QRM at tones 51 and 52. Therefore, if these two difficulties are ignored, this particular run would have been error free, while in reality it had a

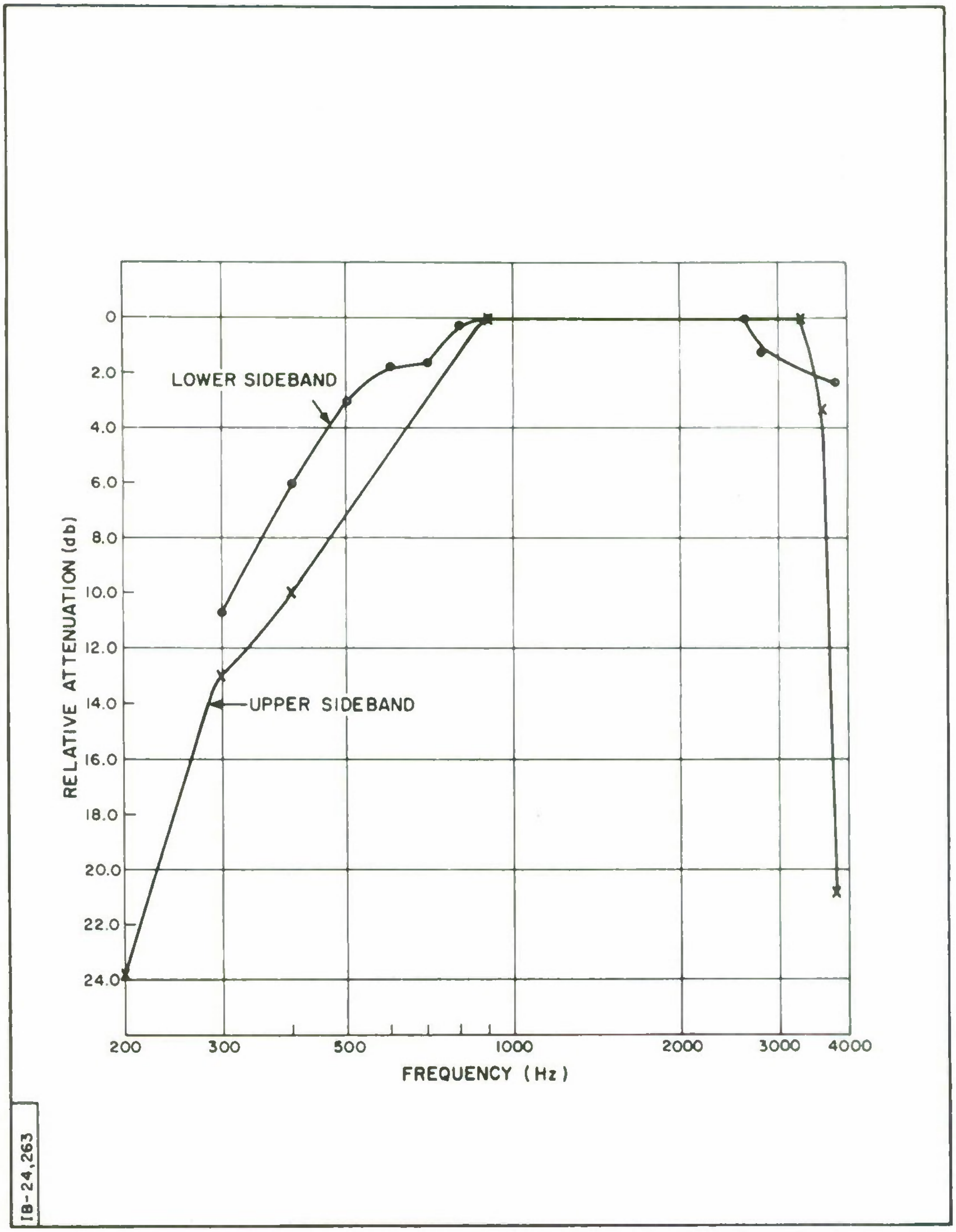

Figure 7. Amplitude Characteristic of the Transmitter

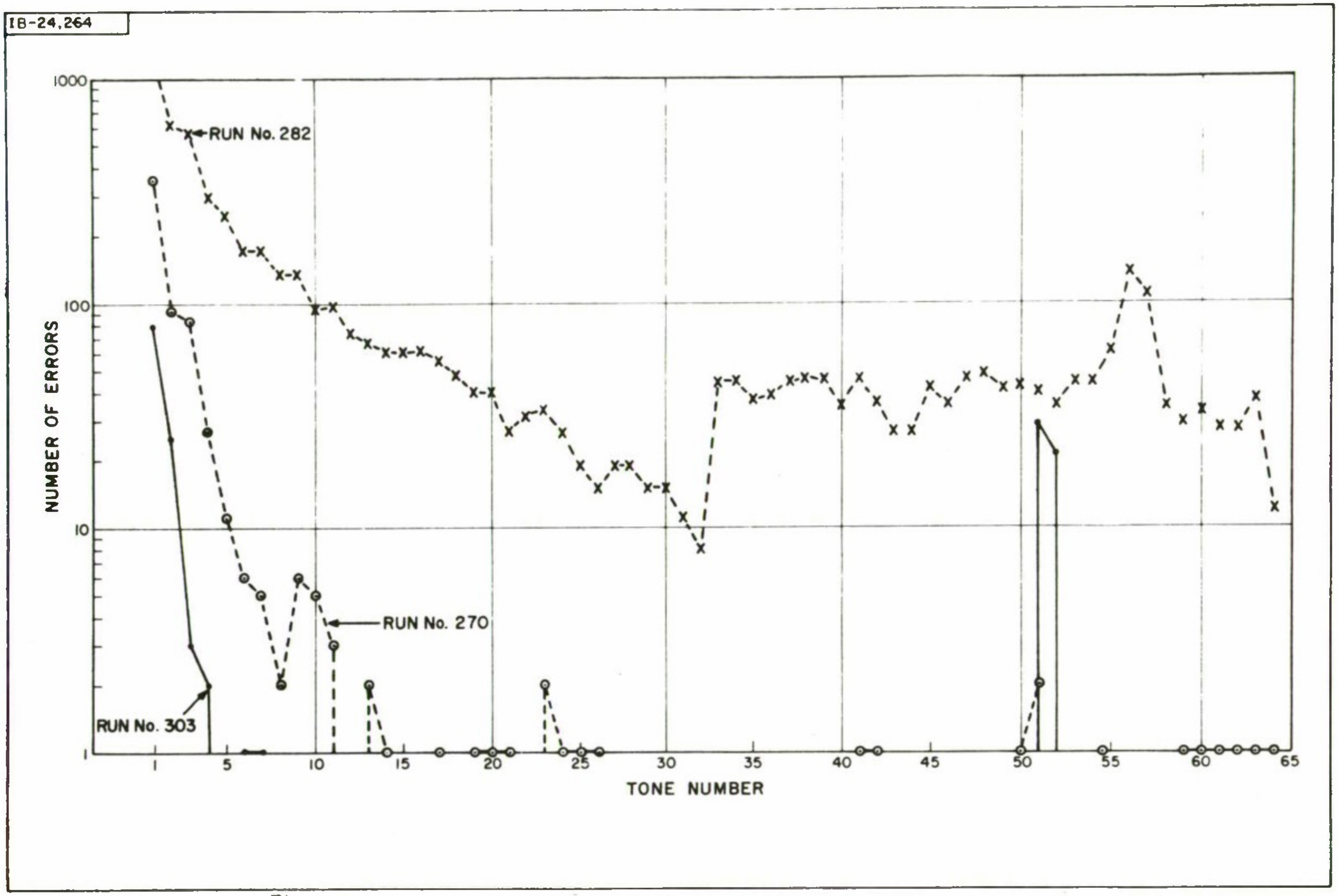

Figure 8. Effect of Transmitter Characteristic on Tone Errors

5.6×10^{-5} error rate. Run 270 had an average error rate of 2.2×10^{-4}; however, if one ignored the errors on the first 10 tones it would have an error rate of 10^{-5}. The transmitter characteristic has a less dramatic effect on the average error rate of run 282. In this case the average error rate of 2.03×10^{-3} would become approximately 10^{-3} or a factor of two better.

The above discussion is meant to illustrate two points. First, the degrading character of the transmitter characteristic was always present and affected different runs differently depending upon the average error rate. Second, the presence of narrowband QRM was quite likely.

SECTION V

THE HF MEDIUM

Digital data transmission through the HF medium is subject to the vagaries of ionospheric propagation. The medium is subject to daily, seasonal, and even longer term variations so that a transfer function characterization of the channel would be virtually impossible. In this section three parameters, namely SNR (signal-to-noise ratio), multipath delay spread, and QRM (man-made interference), which affected the performance of the ANDEFT/SC-320 are discussed from observations made during the tests.

The SNR was observed by recording the voltage of the HF receiver's automatic gain control (AGC). After calibration of the voltage scale, the noise voltage may be recorded in the absence of signal and the signal plus noise voltage may also be recorded; thus, a rough estimate of the SNR may be computed. The best SNR's observed were between 30 and 40 db; however, these SNR's occurred rather infrequently. In general, absorption is higher in the summer months than in other periods of the year. Hence, relatively low SNR's are to be expected.

The range of multipath delay spreads observed at the operational frequencies are shown in Table III below.

Table III

Multipath Delay Spreads

Carrier Frequency (MHz)	Range of Delay Spreads (ms)
7	1.5 - 3.0
13	1.0 - 2.25
18	1.0 - 2.0
22	0.2 - 1.2

The multipath delay spreads were obtained from digital ionograms which were produced from the sounder data gathered during the tests.

Interference (QRM) on all assigned frequencies was present most of the time with the exception of the 22 MHz frequency. When this frequency was able to sustain transmission, it was, in general, free of QRM. The 13 and 18 MHz frequencies also used for daytime transmission were generally jammed with QRM. This explains the relatively small number of samples obtained at these frequencies as shown in the next section. Transmission at night may have been possible on the 7 and 9 MHz frequencies; however, the 9 MHz frequency was never available because of QRM and only one side-band was available at the 7 MHz frequency.

Hence, of the three parameters discussed, the QRM limited the availability of the various channels for transmission. In addition, QRM limited the performance to a great extent since quite often a less desirable path had to be chosen because of the presence of QRM at the more optimum transmission frequencies.

SECTION VI

TEST RESULTS

This section contains the cumulative performance curves of the ANDEFT/SC-320 HF modem. The average bit error rate (BER) data has been computed from the minute-by-minute printouts of error counts. Even though most test runs were of ten-minute duration, a one-minute averaging time was used. At 4800 b/s, 2.88×10^6 bits are transmitted in one minute, which are enough to establish a BER of approximately 10^{-5}.

Figure 9 gives the non-diversity, 4800 b/s, cumulative performance of the ANDEFT/SC-320 HF modem when the data is transmitted at 7, 18, and 22 MHz. The transmitted test pattern utilized was a 52-bit pseudo-random pattern. Table IV summarizes this non-diversity performance by comparing the error rates which were exceeded 50% of the time with the data transmission at different radio frequencies.

Table IV

Non-Diversity Performance of the ANDEFT/SC-320 at 4800 b/s

RF Carrier (MHz)	50% BER
7	2.0×10^{-2}
18	6.3×10^{-3}
22	2.5×10^{-3}

Table IV and Figure 9 show that operation at the higher frequencies where the transmission is noise-limited is much superior to operation at lower frequencies where the transmission is multipath-limited. Comparing the 7 MHz and the 22 MHz frequencies, we note an increase of nearly a full

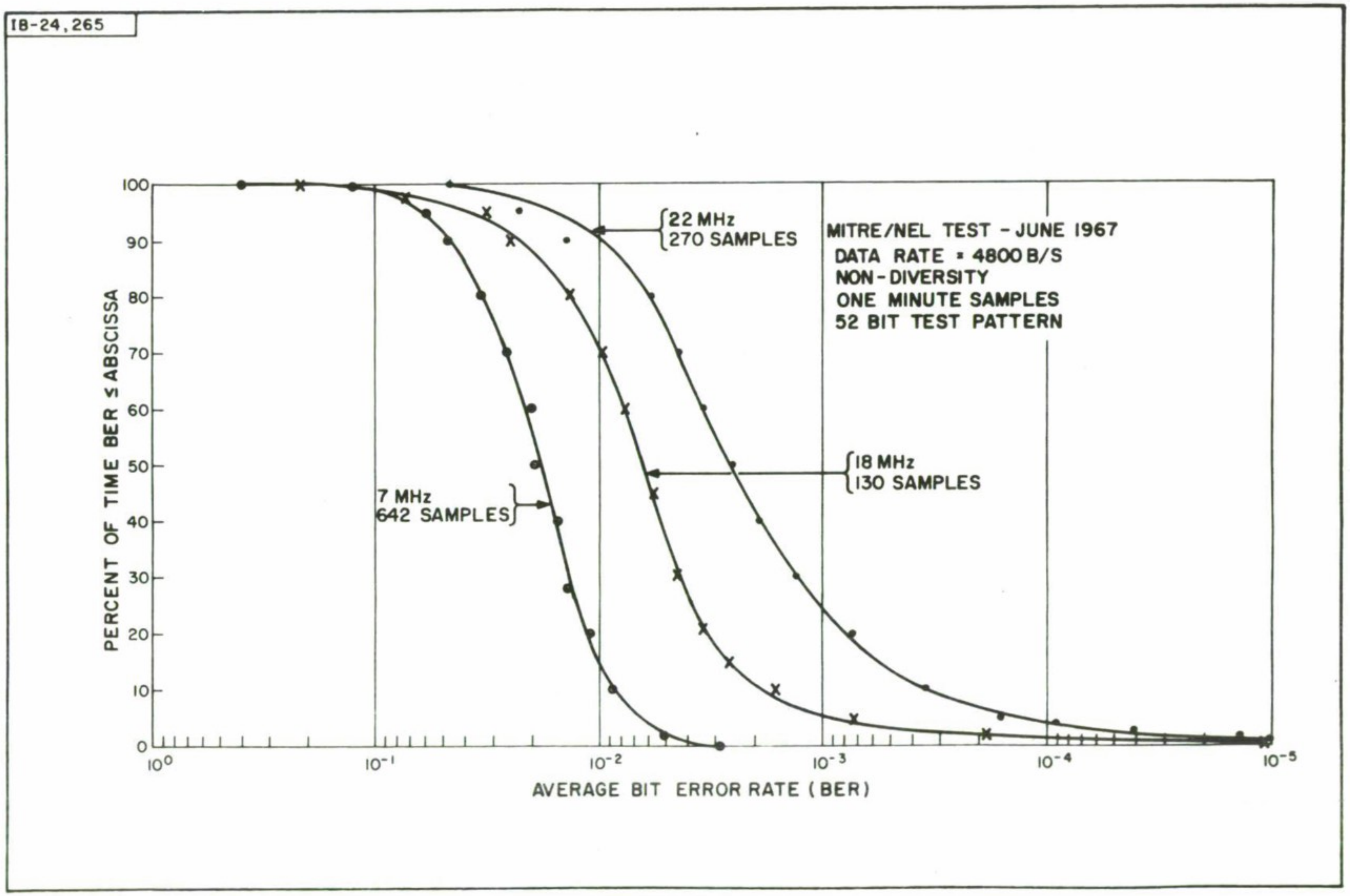

Figure 9. Cumulative Performance Curves of the ANDEFT/SC-320 HF Modem

order of magnitude in the BER which is exceeded 50% of the time. The observed range of multipaths given in Section V was from 0.5 to 1.2 milliseconds (ms) for the 22 MHz frequency, while the range for the 7 MHz frequency was from 1.5 to 3.0 ms. The ANDEFT/SC-320 has a guard space of 1-2/3 ms, which means that this guard space was frequently exceeded when the transmission was at 7 MHz. This guard space and multipath consideration tends to explain the poorer performance at the 7 MHz frequency which was used only at night.

Figure 10 is similar to Figure 9 in that the cumulative performance is compared at the 7, 18, and 22 MHz frequencies, and the 52-bit pattern is used, and no out-of-band frequency diversity (OBD) is used. However, the data rate was reduced to 2400 b/s, and an in-band frequency diversity (IBD) was employed. Notice that operation at the higher frequencies was again preferable and in this instance by a factor of about seven. Also, notice that at 2400 b/s the BER which is exceeded on the average 50% of the time has moved out to 2.5×10^{-4} at the higher frequencies.

Figure 11 compares 4800 b/s operation of the ANDEFT/SC-320 at 13, 18, and 22 MHz when OBD is used and the all-one pattern is transmitted. These curves are presented separately from those where the 52-bit pattern was used because of the possibility of an adverse influence on the BER. Notice that the average BER for the three curves is approximately 2.5×10^{-3} at the point where this BER would be exceeded 50% of the time. This BER is about the same as the one which was obtained for the 4800 b/s, non-diversity mode of operation at 22 MHz with the 52-bit pseudo-random pattern. This result tends to show that higher BER's occurred with the all-one pattern since one would expect some improvement in BER when OBD is used. The primary purpose for recording the all-one data was to obtain a "canned" medium.

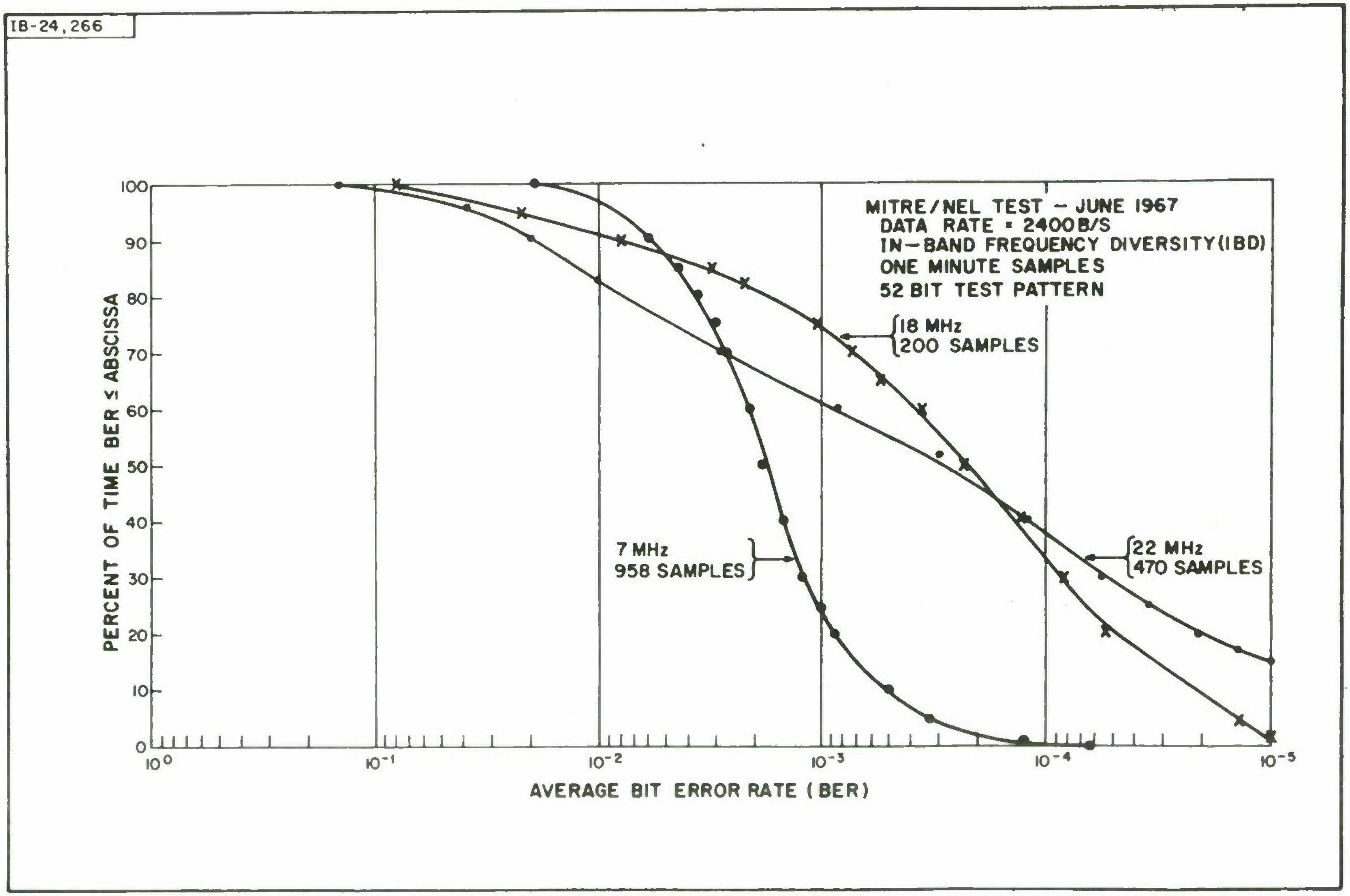

Figure 10. Cumulative Performance Curves of the ANDEFT/SC-320 HF Modem

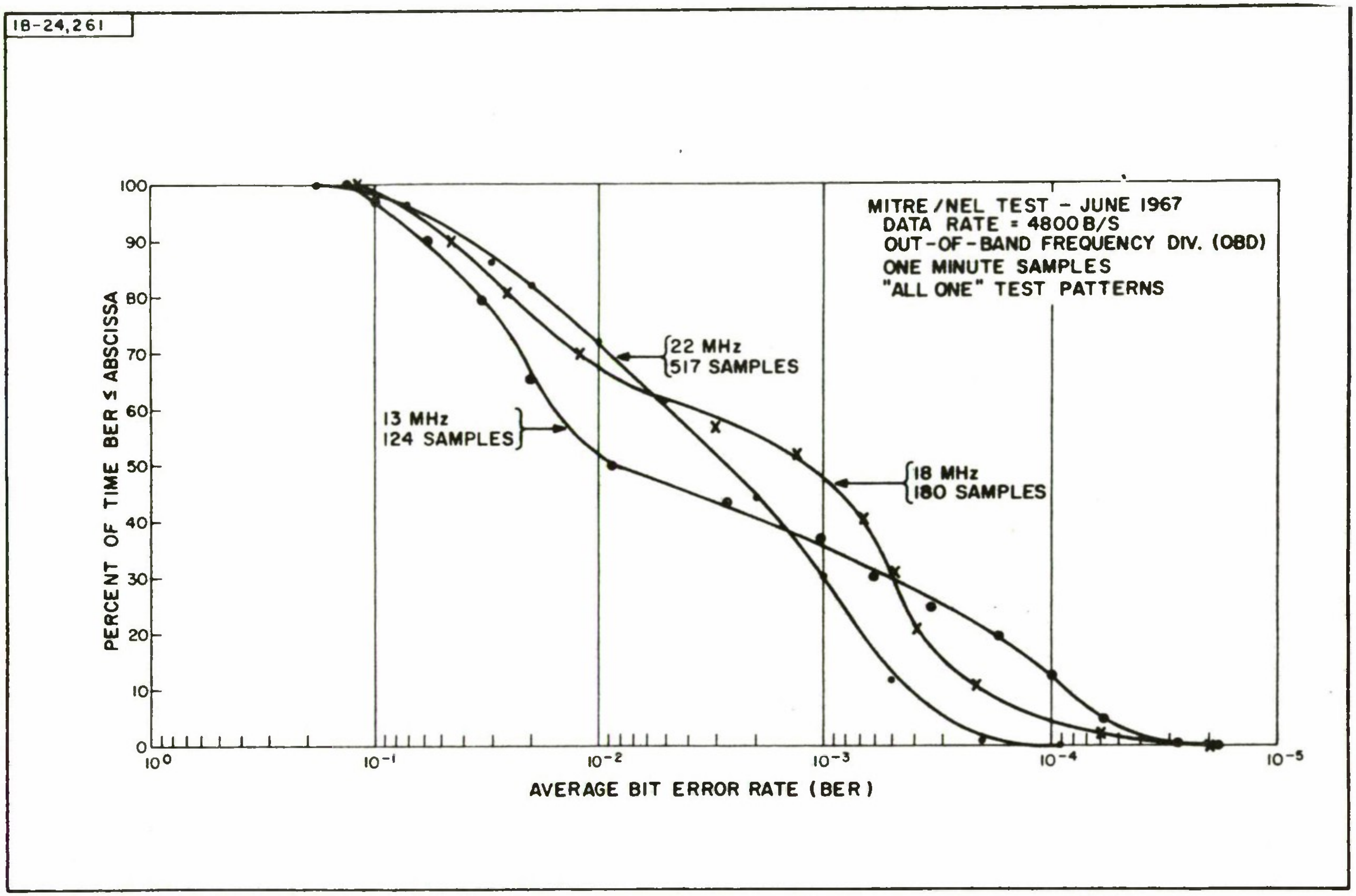

Figure 11. Cumulative Performance Curves of the ANDEFT/SC-320 HF Modem

Figure 12 is a comparison of 4800 b/s non-diversity with 4800 b/s OBD and with 2400 b/s IBD all at 22 MHz when the 52-bit test pattern is transmitted. Table V below summarizes the data by comparing the BER's which were exceeded 50% of the time for the different diversities and data rates at the 22 MHz frequency.

Table V

Comparison of the BER Performance of the ANDEFT/SC-320 at 22 MHz

Data Rate (b/s)	Diversity	50% BER
4800	None	2.5×10^{-3}
4800	OBD	8.0×10^{-4}
2400	IBD	2.8×10^{-4}

Notice that going to OBD at 4800 b/s there is an improvement factor of three and going to IBD at 2400 b/s there is an improvement factor of about ten over 4800 b/s with no diversity. The improvement at 4800 b/s with out-of-band frequency diversity (OBD) is in all probability not typical of the improvement to be expected when dual space diversity is employed. There appear to be at least three disadvantages of OBD when compared to space diversity, and these are as follows: 1) each sideband is transmitted at three db less power, 2) there is a greater susceptibility to QRM since now 6 KHz of bandwidth is required versus 3 KHz, and 3) the possibility of correlated data for small values of multipath (typically less than a 1 ms multipath spread which results in correlation bandwidths greater than 1,000 Hz). In support of the last point, the lowest tones on both sidebands were only 800 Hz apart so that multipath spreads of less than 1-1/4 ms led to some correlation between the data on both sidebands. The correlation and QRM considerations explain to a great extent the improvement factor

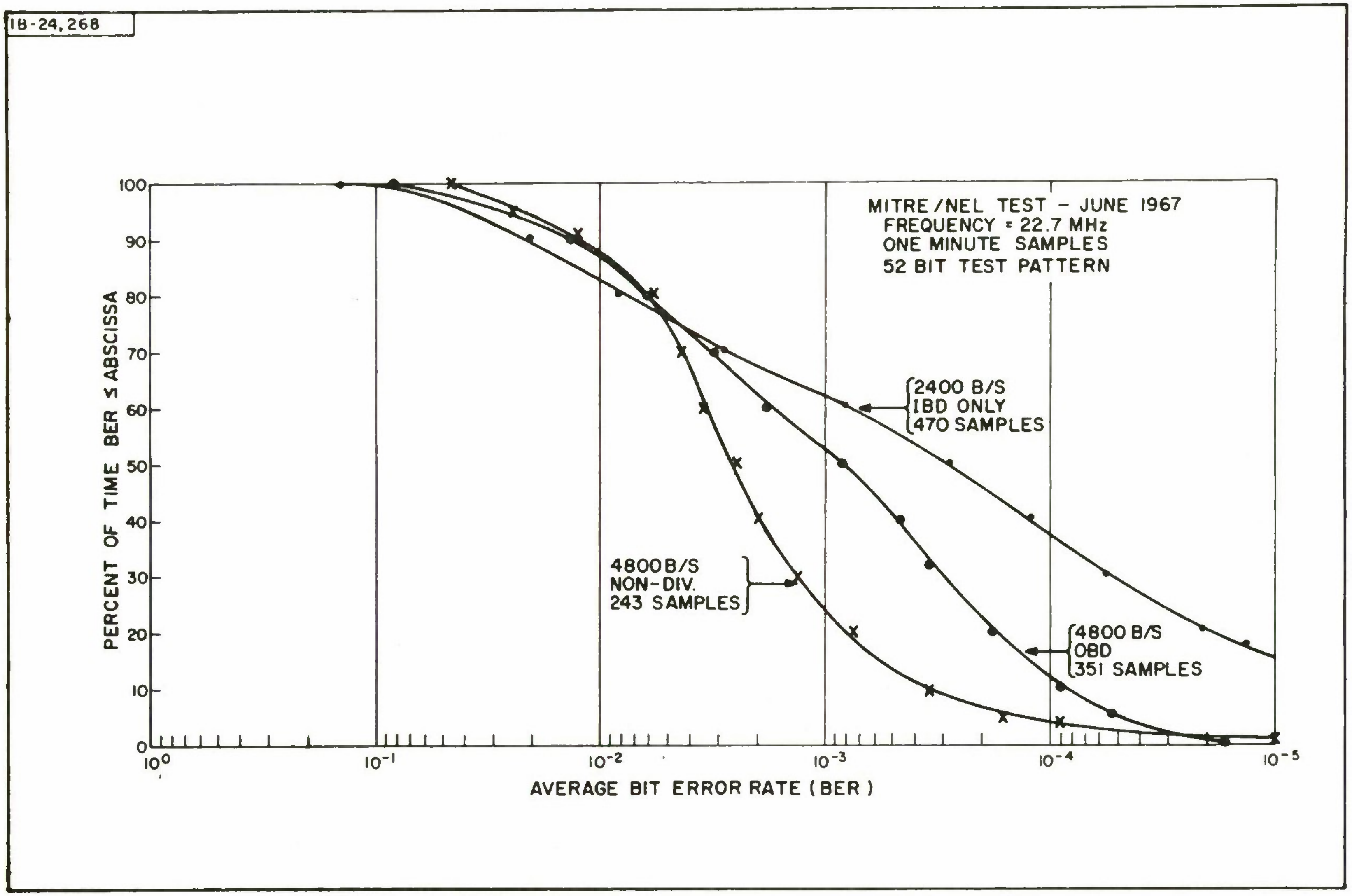

Figure 12. Cumulative Performance Curves of the ANDEFT/SC-320 HF Modem

of ten with IBD at 2400 b/s. In this case only one sideband is used, and the tones carrying the same data are over 1300 Hz apart.

Figure 13 is a comparison of 4800 b/s non-diversity with 2400 b/s IBD at 7 MHz when the 52-bit test pattern is transmitted. The cumulative performance curve for the 2400 b/s data rate with IBD is shifted to the right by roughly an order of magnitude. The substantial diversity improvement is probably due to the uncorrelated nature of the data. Unfortunately, no data was collected at 4800 b/s with OBD because of the constant presence of severe QRM on one of the sidebands which precluded the use of OBD.

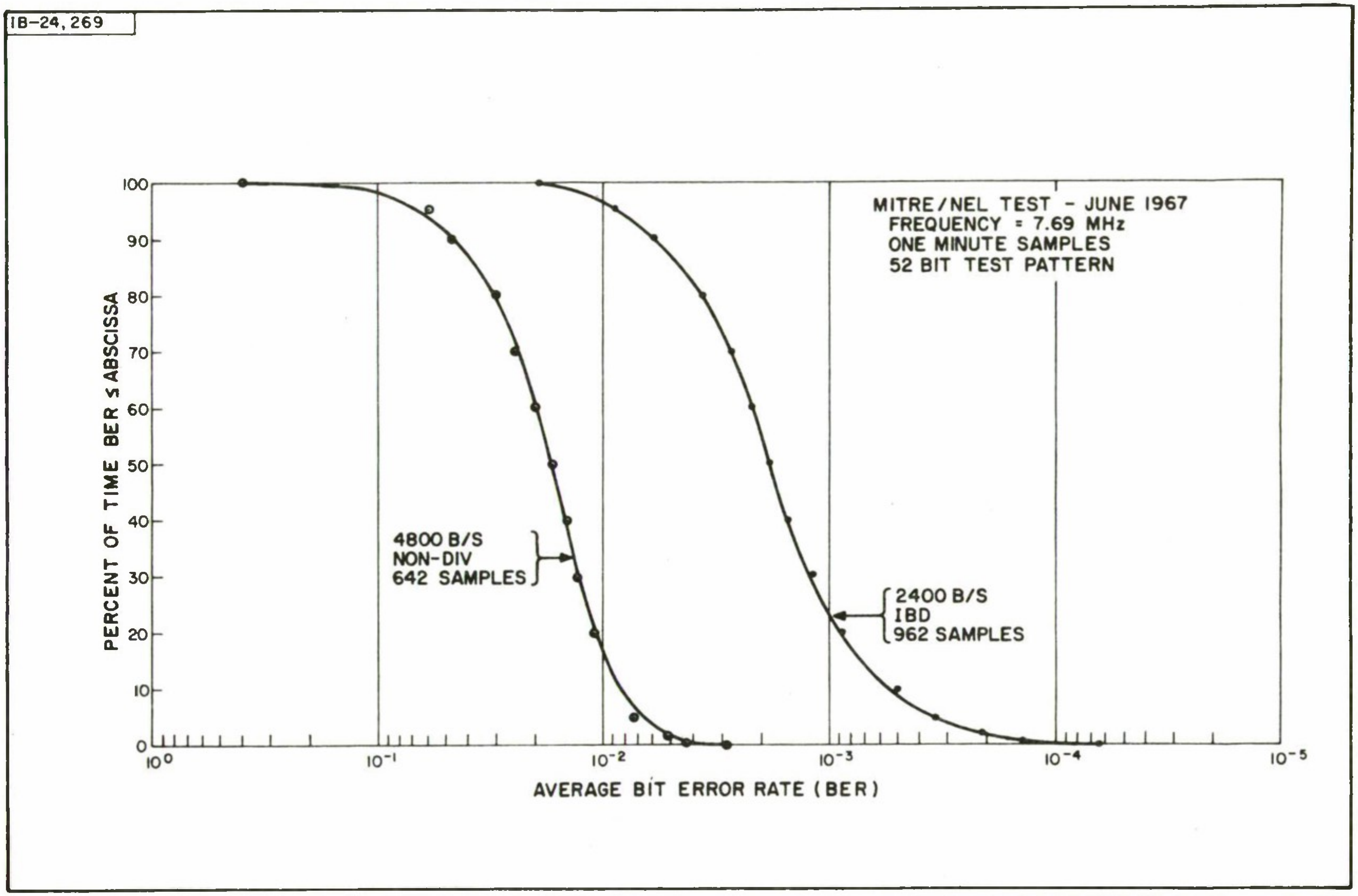

Figure 13. Cumulative Performance Curves of the ANDEFT/SC-320 HF Modem

SECTION VII

CONCLUSIONS

The modems that are available commercially for transmission through the HF medium are limited to data rates of about 2400 b/s. The ANDEFT/SC-320 development program was undertaken to achieve the capability of transmitting at least 4800 b/s through the HF medium with an acceptable error rate. The MITRE-NEL HF transmission tests successfully demonstrated that the ANDEFT/SC-320 HF modem is capable of transmitting data at a rate of 4800 b/s with error rate performance comparable to present 2400 b/s HF modems [3, 4] .

Some specific conclusions drawn from the test results are the following:

(1) the modem performed best at the higher assigned frequencies,

(2) the improvement with in-band frequency diversity was greater than with out-of-band frequency diversity when both are compared to non-diversity, and

(3) the factor which limited the collection of data more than any other was the presence of QRM at the assigned frequencies.

REFERENCES

1. M. P. Talbot, Jr., "Summary-Acceptance Tests of the ANDEFT/SC-320 HF Modem," Contract No. AF 19(628)-5165, The MITRE Corporation, Bedford, Mass., ESD-TR-66-338, 23 December 1966.

2. W. F. Walker, "Baseband Multipath Fading Simulator," Radio Science, Vol. 1, No. 7, pp. 7663-7667, July 1966.

3. R. E. Greim, W. R. Menges, F. N. Nelson, Jr., "Comparative Performance Evaluation of Digital Data Modems for HF Radio," Contract No. AF19(628)-5165, The MITRE Corporation, Bedford, Mass., ESD-TDR-64-631, AD610675, 1 October 1964.

4. W. F. Longchamp, "Error Rates for High-Speed Digital Data Transmission on ETR HF Radio Circuits," Contract No. AF 19(628)-5165, The MITRE Corporation, Bedford, Mass., ESD-TR-66-86, 28 February 1966.

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13. ABSTRACT

During June 1967, digital data transmission tests were conducted on a High-Frequency radio circuit between MITRE and the Naval Electronics Laboratory. The HF modem tested was the ANDEFT/SC-320 which was designed by General Dynamics/Electronics Division for data transmission at rates of 4800 b/s in a 3 KHz bandwidth. The test results demonstrate that this modem which operates at twice the data rate of current HF modems has comparable bit error rate performance.

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Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
DIGITAL DATA TRANSMISSION SYSTEMS WITH (HF)						
MULTICHANNEL RADIO SYSTEMS						
RADIO COMMUNICATION SYSTEMS WITH (HF)						
IONSPHERIC TRANSMISSION						